Energy and the Economy

Energy and Economic Growth: The Stylized Facts

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What overall patterns, or stylized facts, characterize the relationship between economic growth and energy use both across countries and over time? Energy economists and economic historians have investigated these issues, but existing research has either looked at how energy use and economic development vary across countries at one point in time or how they evolve over time in individual countries or groups of countries. Researchers have not linked together the cross-sectional and time series behaviors despite their obvious dependence on each other.

We investigate the links between the time and cross-sectional (or income per capita) dimensions using two datasets. One is a dataset for 99 countries from 1971 to 2010 that uses IEA and Penn World Table data. The other comprises historical data for the U.S. and a number of European and Latin American countries that extends back to 1800 for the U.S. and some Northern European countries and to later dates in the 19th and early 20th century for the other countries.

In recent years, economic historians, including one of the authors of this paper, Mar Rubio, have been working to reconstruct the energy history of many countries in Europe and the Americas for the years before the Second World War. Some of the historical data we use was prepared for the recently published Power to the People, authored by Astrid Kander, Paolo Malanima, and Paul Warde and published by Princeton University Press. Mar Rubio collaborated with Kander et al. on the Spanish data for that volume and led a team that developed historical data for Latin America. Though these data are obviously much more uncertain than those for recent years, they can provide insights into the long-run relationship between energy and economic development.

Our key finding from the recent data is that there has been a fairly stable relationship between countries' GDP per capita measured in purchasing power parity adjusted Dollars and their per capita energy use over the last 40 years. A 1% increase in income per capita across countries is associated with a 0.7% increase in per capita energy use. This implies that energy intensity (energy use/GDP) is lower in richer countries and that on average a 1% increase in income per capita is associated with a 0.3% decrease in energy intensity.

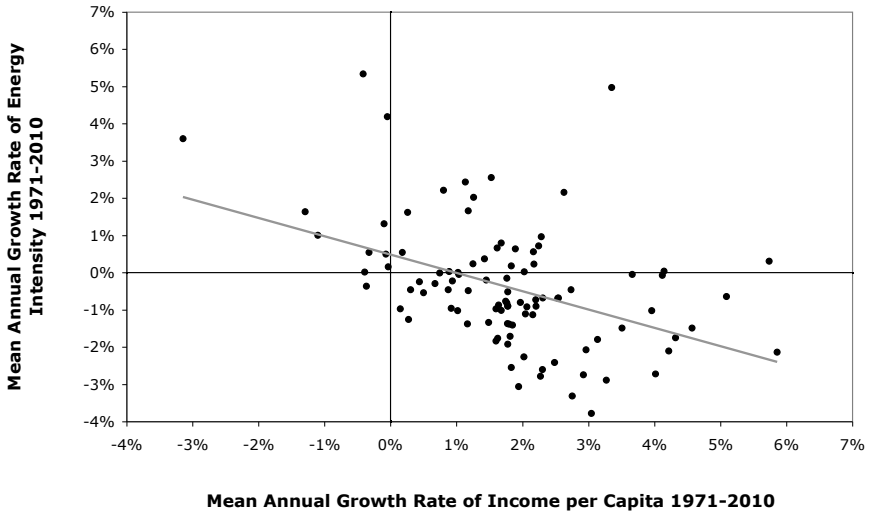

Figure 1. Relationship between the growth rates of energy intensity and income per capita for 99 countries from 1971 to 2010. Source - IEA and Penn World Table 7.1.

The relationship is also stable in the sense that the average energy use per capita associated with any given level of income per capita has not changed over the four decades. This means that the typical country only managed to reduce its energy intensity by increasing its income per capita. A different way of looking at the same data is to compare countries' average GDP per capita growth rate from 1971 to 2010 to the rate of change in their energy intensity over the same period. This relationship is shown in Figure 1:

The graph shows that higher rates of economic growth are associated with higher rates of decline in energy intensity. The graph also shows that if a country's economic growth was zero then not only did its energy intensity not decline, but actually it increased on average.

Figure 1 also indicates that there are many countries where energy intensity rose despite economic growth. Our second main finding is that there was convergence in energy intensity over time and that the countries whose energy intensity rose typically had low energy intensity at the beginning of the period. Countries that were very energy intensive typically saw declines in energy intensity. There is now a tighter relationship between income and energy use than there was forty

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years ago.

In other words, though there has been some degree of "decoupling" of energy and growth in some formerly energy intensive economies, this has not been the common experience. Rather, there has been a homogenization, with countries increasingly resembling each other, while energy intensity globally has declined, but not by enough to reduce energy use.

This picture is borne out in the historical data too. Figure 2 shows the evolution of energy intensity and income over the last two centuries for four representative countries. Energy intensity appears to have declined the most in the United States, which was the most energy intensive economy in the 19th Century. On the other hand, energy intensity has been fairly stable in Spain, which was a very low energy intensity economy in the 19th Century. These time-paths are superimposed on the global distribution of energy intensity and income in 2010. This shows that in the past the United States was more energy intensive for its income level than any countries are today but that in the last few decades it has ceased to be remarkable in that way. On the other hand, the time paths of Sweden, Brazil, and Spain are mostly within the present day energy intensity distribution.

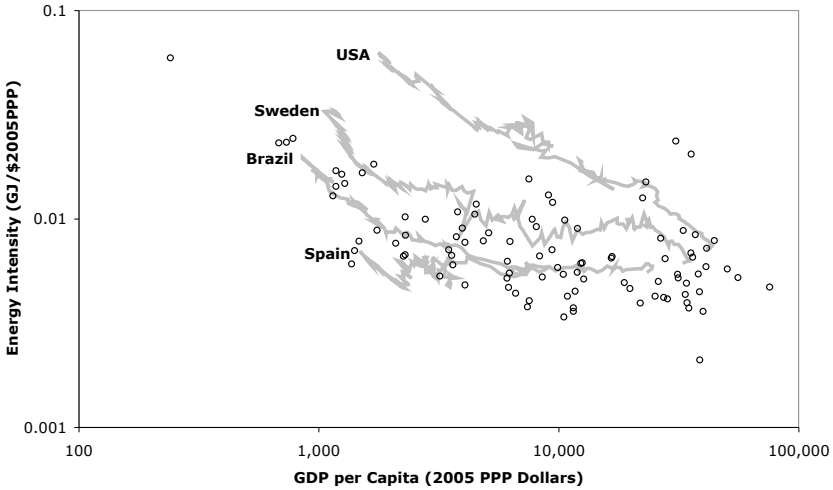

Figure 2. Relationship between energy intensity and GDP per capita. Circles: 99 countries in 2010. Sources – IEA and Penn World Table 7.1. Lines: Historical development of energy intensity and income per capita for the four countries marked. US and Swedish data are for 1800-2010; Spain, 1850-2010; Brazil, 1890-2010. Sources – see conference paper for details.

Our paper in the online proceedings also covers other regularities in the data. Specifically, there is some evidence that the share of energy in costs declines over time. But this "stylized fact" is still more of a prediction than a proven regularity. As is well known, the quality of energy increases over time and with income as countries have transitioned from traditional biomass, to fossil fuels, to primary electricity over time. We also find that the energy/capital ratio, which is an alternative to energy intensity as an indicator of overall energy efficiency, behaves somewhat similarly to energy intensity.

Future theoretical models of the relationship between energy use and economic development will need to take these stylized facts into account and make sure that their predictions match the facts. The stylized facts might also be useful for developing simple business as usual energy use scenarios.